Stanford University
Computer Science Department

Fall 2004 Comprehensive Exam in Artificial intelligence

1. **Closed book. Write only in the Blue Book provided.**
2. **The exam is timed for one hour.**
3. **Write your Magic Number on this sheet & on the Blue Book.**

The following is a statement of the Stanford University Honor Code:

A. The Honor Code is an undertaking of the students, individually and collectively:

1. that they will not give or receive aid in examinations; that they will not give or receive un-permitted aid in class work, in the preparation of reports, or in any other work that is to be used by the instructor as the basis of grading;

2. that they will do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and letter of the Honor Code.

B. The faculty on its part manifests its confidence in the honor of its students by refraining from proctoring examinations and from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above. The faculty will also avoid, as far as practicable, academic procedures that create temptations to violate the Honor Code.

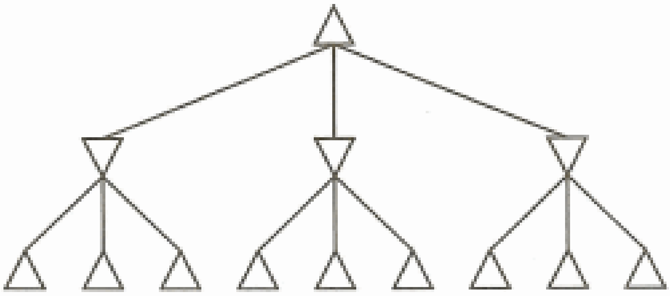
C. While the faculty alone has the right and obligation to set academic requirements, the students and faculty will work together to establish optimal conditions for honorable academic work.

By writing my Magic Number below, I certify that I acknowledge and accept the Honor Code.

Magic Number ---------------------------------

2004 Comprehensive Examination
Artificial Intelligence

1. **Search.** (20 points) Consider the game tree shown below. Upward-facing triangles are maximizing nodes, and downward-facing triangles are minimizing nodes.



(a) Assign the payoffs 1, 2, 3, 4, 5, 6, 7, 8, 9 to the terminal nodes of this tree in such a way that α-β pruning eliminates as *many* nodes as possible.
(b) Assign the payoffs 1, 2, 3, 4, 5, 6, 7, 8, 9 to the terminal nodes of this tree in such a way that α-β pruning eliminates as *few* nodes as possible.

2. Logic. (20 points) A *theory* is a set of sentences closed under logical entailment. A theory is *complete* for a language if and only if every sentence in the language *or* its negation is in the theory. Now, consider the language consisting of all sentences in First-Order Logic (1) that can be formed from just one unary relation constant p and two object constants a and b, (2) that includes variables x, y, z, ..., but (3) that does *not* include functions, explicit quantifiers, or equality. Which of the following sentences logically entails a theory that is complete for all sentences in this language?

(a) $p(a) \wedge p(b)$
(b) $p(a) \wedge \neg p(b)$
(c) $p(x)$ (equivalent to $\forall x.p(x)$)
(d) $p(a) \vee \neg p(a)$
(e) $p(a) \wedge \neg p(a)$

3. Automated Reasoning. (20 points) Use the resolution refutation method to prove $\exists x.\exists y.(p(x,y) \wedge q(x,y))$ from the following premises.

$$\exists x.\forall y.\ (p(x,y) \Leftrightarrow q(x,y))$$
$$\forall x.(\exists y.p(x,y) \vee \exists z.q(x,z))$$

Note that this is a question about the resolution refutation method. You will get zero points, nothing, nada, zip, no score for proving it in any other way.

4. Probability. (20 points) Adapted from Nilsson's *Artificial Intelligence: A New Synthesis*. Suppose that colored balls are distributed in three indistinguishable boxes, B1, B2, and B3, as shown in the following table.

	B1	B2	B3
Red	2	4	3
White	3	2	4
Blue	6	3	3

A box is selected at random from which a ball is selected at random. The ball is red. What is the probability of the box selected being B1? Unreduced fractions are okay.

5. Natural Language. (20 points) Consider the augmented phrase structure grammar shown below.

$S(r(x, z) \wedge r(y, z)) \rightarrow Q(r(both(x,y), z))$
$Q(w(u, v)) \rightarrow NP(u)\ Verb(w)\ NP(v)$
$NP(x) \rightarrow Noun(x)$
$NP(both(x, y)) \rightarrow NP(x)$ ***and*** $NP(y)$
Noun(tom) → ***Art***
Noun(dick) → ***Bob***
Noun(harry) → ***Cal***
Noun(mary) → ***Deb***
Verb(hates) → ***hate***
Verb(hates) → ***hates***

(a) Given that *s* is the top-level non-terminal, is there a semantic interpretation for the expression ***Deb hates Art and Bob***? If so, what is it?

(b) Given that *s* is the top-level non-terminal, is there a semantic interpretation for the expression ***Art and Cal hate Deb***? If so, what is it?

(c) Change the augmentations on the existing rules to eliminate ungrammatical sentences like *Art and Cal hates Deb* (without eliminating the corresponding grammatical sentences). If you are unable to do this, you can still get partial credit by changing the rules themselves.